International **C**rane **S**takeholder **A**ssembly

- Guidance -

Lifting A Load With Several Mobile Cranes (Multiple Crane or Tandem Lifting)

Members are:

- **Association of Equipment Manufacturers [AEM]**
- **The Crane Industry Council of Australia [CICA]**
- **The European Association of abnormal road transport and mobile cranes [ESTA]**
- **European Materials Handling Federation [FEM]**
- **Specialized Carriers & Rigging Association [SC&RA]**

Legal Note: *This publication is only for guidance and gives an overview regarding in the assessment of risks related to lifts where a load is lifted with several mobile cranes. It neither claims to cover any aspect of the matter, nor does it reflect all legal aspects in detail. It is not meant to, and cannot, replace own knowledge of the pertaining directives, laws and regulations. Furthermore the specific characteristics of the individual products and the various possible applications have to be taken into account. This is why, apart from the assessments and procedures addressed in this guide, many other scenarios may apply.*

CONTENT

1. INTRODUCTION

There are additional hazards associated with lifting a single load using multiple mobile cranes when compared to lifts involving only one crane. Most publications about a multiple crane lift identify it as a “critical lift” irrespective of other circumstances of the lift (e.g. weight of load, center of gravity).

Simultaneous movement coordination of the cranes involved is crucial to avoid negative influences such as side forces acting on the crane boom or unintended load distribution. Lifting with unequal hook speeds, for example, might result in a change of the load distribution between the involved cranes which can result in overloading of one or more of the cranes.

Cranes involved in a multiple crane lift are typically controlled by the individual crane drivers and therefore the human factor must also be considered. Even if the operators do not make any mistakes, it is virtually impossible to perfectly synchronize the operation, which could result in dangerous situations.

2. SCOPE

This document applies to mobile cranes and is considered as complementary information to the machine operator’s manual. It is meant to provide guidance in the assessment of risks and contains information related to the use of mobile cranes for multiple crane lifting where the cranes are operated separately under control of more than one operator.

Lifting operations with intentional load shifting from crane to crane (e.g. tailing, panel tilting) are not covered by this guideline.

NOTE: Cranes with interconnected control system to ensure the synchronization of movements (e.g. mobile harbor cranes equipped with such systems) should follow the requirements of ISO 12480-1, Chapter 11.4.4.

3. STANDARDS AND REGULATIONS

There are various standards and regulations from different countries that address the complexity of multiple lifts and provide crane operating companies with guidance for such operations:

- Accident Prevention Regulation for Cranes (“Unfallverhütungsvorschrift Krane”) BGV D6 issued by the German Institutions for Statutory Accident Insurance and Prevention.
- ASME B30.5-2014 Mobile and Locomotive Cranes
- ASME P30.1-2014 Planning for Load Handling Activities
- Australian Standard AS2550.1-2011 Cranes, Hoists, and Winches - Safe Use - General Requirements, Section 6.28 Multiple Hoist or Crane Operation.
- BS 7121-1:2006: British Standard Code of Practice for Safe Use of Cranes (Part 1: General).
- BS 7121-3:2000: British Standard Code of Practice for Safe Use of Cranes (Part 3: Mobile Cranes).
- EN13155: Non-fixed load lifting attachments
- ISO standard 12480-1 (Cranes – Safe use – Part 1: General/Paragraph 11.4: Multiple lifting.
- Safety and Health in Ports. ILO Code of Practice; Geneva, International Labor Office, 2005.
- Werkinstructie VVT 109 from VVT – Netherlands

There may be other standards to consider depending on location (e.g. local, state, country regulations).

ISO 12480-1 provides guidance to the crane operating company for the safe use of cranes under different circumstances (Cranes – Safe use – Part 1: General/Paragraph 11.4: Multiple Lifting).

- **The main items of this standard include: side forces on the crane boom must be avoided, if possible, with appropriate instrumentation and crane movements have to be coordinated.**
- **In addition, ISO 12480-1 allows cranes to use up to 100% of their rated capacity, if special preconditions are maintained. If the preconditions are not given, a down-rating of 25% or more may be necessary.**

4. GUIDELINES

When mobile cranes are used to perform a multiple crane lift, certain precautions are necessary. The following guidelines are based on the above standards/regulations and on manufacturers' knowledge and experience. These should be reviewed before starting any multiple crane lift and considered during each phase of the lifting project:

4.1. Lift Engineering/Planning:

Each multiple crane lift using mobile cranes requires a detailed engineering study. During the planning and the engineering of the lift, particular attention shall be focused on the following points:

- **Crane models:**

  Similar crane models, configurations and reeving should be used.

  If the lifted loads are intended to be equally distributed between the cranes, the use of same crane models or at least models of the same capacity range will help to ensure comparable operating speeds and similar loading of the cranes. If the lifted loads are intended to differ between the cranes (e.g. one main crane/load and one smaller crane/load), the crane capacities will be selected accordingly. In this case, operating the cranes with similar capacity utilization will provide a consistent lift capacity safety margin.

  If the cranes have different characteristics (e.g. operating speeds, system stiffness), the movement of the cranes may not be able to accurately synchronize. An assessment should be made of the effect of variation in plumb of the hoist ropes, which could arise from inequalities of speed, together with a determination of the means for keeping such inequalities to a minimum.

- **Position of the cranes:**
  - The cranes should be positioned to minimize side loads on their booms.
  - Whenever possible the cranes should be arranged to avoid slewing due to the risk of inducing side loads on the booms is very high during slewing operations.
  - Check relative positions (cranes, attachment points, boom tips, etc.) at each stage of the lifting operation to ensure that no collisions can occur (between cranes and with external obstacles).

- **Ground preparation:**

  Make sure that the ground resistance is sufficient in all positions and take into account that the ground pressures can add up if the cranes stand close to each other. Additional considerations are required if cranes are supported on barges.

- **Travel:**

  Crane travel is common with multiple crane lifts. Crane travel speeds and additional capacity deration should be considered.

- **Weather:**

  \- Certain weather conditions such as thunderstorms, strong winds, heavy rains, ice or snow can impose additional loads on a crane and adversely affect the safety of crane operations.

  \- The crane should not be operated in wind speeds that are in excess of those specified in the operating instructions for the crane. Gusting wind conditions can have an additional adverse effect on the safe handling of the load and the safety of a crane.

  Instructions issued by the crane manufacturer regarding the out-of-service conditions shall be strictly followed.

- **Lifted Load:**

  The load to be lifted and its center of gravity shall be precisely known:

  - Weight of the lifted load, including the weight of the lifting gear. The lifted load may be increased by e.g. casting and rolling margins, manufacturing tolerances, paint, corrosion, dust, ice and snow.

    The lifted load shall include the weight of the lifting accessories/attachments. When handling heavy or awkwardly shaped loads, the deduction from the rated capacity of the crane to allow the additional weight of the lifting accessories/attachments might be significant. The weight of the lifting accessories/attachments, and hook blocks, where appropriate, and its distribution should therefore be accurately known.
  - Position of the center of gravity of the entire lifted load. Due to the rolling margins, manufacturing tolerances, paint, corrosion, dust, ice, snow, fluid, rain water etc., the center of gravity of the load might not be known accurately and the load distribution between the cranes could therefore be uncertain, fluids may move the center of gravity during the lift.
  - Wind sail area and projected surfaces. Wind sail area/surface is particularly crucial on job sites exposed to wind. Even in relatively light wind conditions, extra care should be taken when handling loads presenting large sail areas and/or big drag factors. (FEM has a guideline FEM 5.016 - *Safety Issues in Wind Turbine Installation and Transportation*[1] which can be used.)
  - When lifting a load with 2 or more cranes, the slewing gear brakes should be released in order to avoid side loadings due to uncoordinated slewing movements. Only one crane should use the slewing gear brake to control this movement, be aware that in this case the slewing gear of only one crane might take the wind loads. Therefore the allowable wind speed shall be calculated accordingly. When the slewing movement is finished, all slewing gear brakes shall be reapplied.

    NOTE: the above guidance applies only to certain lifts with "parallel" crane movements but not to tandem lifts where the load is picked in front of the crane and set down between the cranes.)

- **Rated capacity**
  - An extra safety margin should be incorporated into the lift plan to cover the aspects that lead to an increase of the loading of the individual crane(s). The evaluation of these factors (described in this document) can lead to a reduction of the permissible lift capacity for each crane.

    NOTE: some local/national regulations or standards may specify derating values, depending on the number of cranes involved.
  - When lifting a load with more than one crane without the use of lifting beams, one or more cranes may be quickly overloaded if one or more cranes lift or lower the load depending on the position of the center of gravity of the load. In this case, neither of the rated capacity limiters will stop the load increasing movement. Therefore the utilization of the cranes' rated capacity should be

[1] FEM Guideline: http://fem.uniweb.be/index.php/prodGroups_cranes/en/

reduced depending on the position of the center of gravity of the load and the position of the lifting point of each crane.
See Annex 1 for an example of the calculation method.

NOTE: Here the risk analysis of the lift, the role of the lift supervisor and the reliable communication with the operators are crucial to prevent an accident, see chapter 4.2. Extreme caution shall be given here and the movements shall be extremely slow to be able to anticipate any unexpected load increase and take corrective actions.
See an illustration of this effect in Annex 2.

- **Lift Rigging / Equalizer beams**

  The use of devices such as equalizer beams can help to reduce the risk of unintended load distribution of the cranes due to uncoordinated vertical movements. See Annex 3 for examples.

  Such devices should be included in the engineering/planning of the lift and must be appropriately selected and dimensioned.

  The distribution of forces within the lifting accessories/attachments that arise during the lifting operation should be calculated. The lifting accessories/attachments used should, unless specially designed for the particular lifting operation, have a capacity margin well in excess of that needed for its proportioned load.

- **Risk assessment**

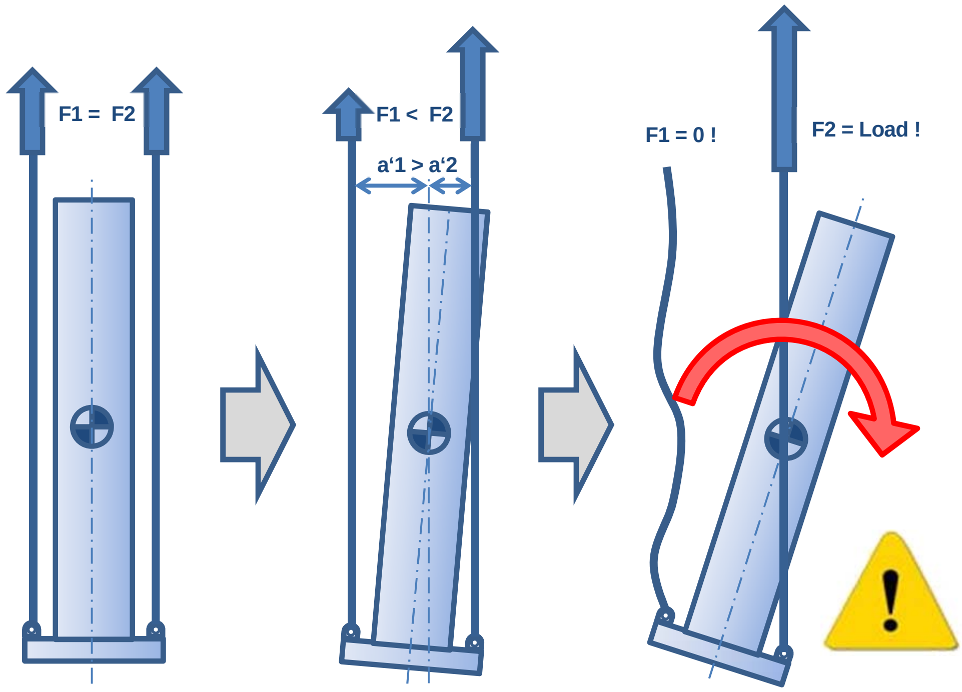
  Before starting a multiple lift with mobile cranes, a detailed risk assessment of the planned lift shall be done for each phase of the lift and shall include as a minimum the following:

  - **Evaluation of load distribution between the cranes**

    This analysis should include possible shifting of the center of gravity during the lift. Such shift may occur due to movements of the load, change of the mass distribution of the load (e.g. fluids moving in containment), wind or other influences.

    Rigging attachment above the center of gravity is a preferred method of attachment for load stability.
    NOTE: If the lifting points are below the center of gravity of the load, an additional risk of tilting (e.g. due to non-synchronous movements) exists. (unstable equilibrium) → see illustration below

Illustration of the risk of toppling if the rigging attachment is below the center of gravity of the load.



- **Analysis of possible side loading**
  - Cranes are designed to withstand limited side forces on the crane booms. Although these forces are part of the load assumptions taking into account accelerations/decelerations of crane and load as well as limited wind forces on crane boom and load, it is unsafe to rely on this lateral strength to withstand horizontal loads of out-of-plumb lifts.

    Attention: The rated capacity limiter of the crane does not measure secondary load effects such as side loads!

  - Side loads can occur due to:
    - uncoordinated crane motions (one crane faster/slower than the other(s)), e.g.: uncoordinated luffing/hoisting/slewing with 2 cranes attached to one load will automatically lead to side loadings on the booms. In certain cases (following a thorough analysis), this effect might be reduced if only one crane uses the slewing gear brake.
    - ground-imperfection, e.g. local settling during travelling
    - crane not level
    - slewing a load with 2 or more cranes; special caution is required when one crane is actively slewing, it will rotate the second crane by “pushing” or “pulling” it! This will induce a side load on both cranes. If the load radius is small, the created side loads may become critical, especially if the cranes are configured with long boom combinations.
    - swinging of a load
    - wind influence, especially when lifting loads with large wind sail areas. Special care should be given on this aspect in the case where the slewing brakes of one or more cranes are released, providing less resistance to wind load.
    - listing of cranes on barges
    - human error during operations

- Excessive side loads may also affect the structural integrity of the load itself and its attachment points.

4.2. Organization and Supervision

A qualified person should be in attendance and in overall control of a multiple crane operation and shall be appointed as supervisor. Only this person shall give instructions to personnel operating machines except in an emergency, when a commonly recognized stop signal may be given by any person observing a situation leading to danger.

If all the necessary points cannot be observed from one position, other personnel are required at various positions to observe and report to the supervisor in charge of the operation. The supervisor shall review the lift operation with the crane operators and other persons involved prior to the lift and define the rules and procedures (communication, emergencies, etc.)

It may be advisable to perform a test lift without load and to execute all movements to confirm the correct configuration and sequences.

4.3. Communication

- The engineered lift should have a lift plan with a stepwise approach documented with intermediate checkpoints to allow step by step checking to determine the planned results are achieved. This lift plan needs to be communicated to all people involved. Any change must be documented and again communicated.
- Ensure efficient communication: crane operators must be able to report their actual status to the supervisor to allow him to get the full picture at any time of the lift. The communication signals/commands should be such to avoid misunderstandings, unintended movements in case of communication breakdown.

4.4. Crane operations and motions

- Crane motions must be coordinated very precisely by the supervisor. He must have continuous contact to all crane operators (e.g. via radio).
- Crane motions shall be performed at reduced speed.
- Crane motions shall be properly coordinated; any deviation shall lead to a stoppage and re-adjustment/re-alignment of the cranes.
- The slewing lock of each crane should always be disengaged during the lifting operation: slewing locks are designed to maintain and secure the crane superstructure in certain positions and to protect the slewing gear (slew ring + pinion).
  During the whole lifting operation, the hoist ropes and their verticality shall be continuously monitored (visually or with instruments); any observation of an out-of-plumb situation shall lead to a stopping of the operation and an evaluation of the cause(s). Re-adjustment may be necessary.

ANNEX 1 Influence of load geometry - Simplified Calculation Method

The following is a simplified method of determination of the rated capacity of the cranes when used in tandem lift operations and with lifting points being above the center of gravity of the load.
When lifting a load with 2 cranes, the load distribution between both cranes can be significantly affected by two phenomenon:

1) Non symmetrical load:

This means that the center of gravity of the load is not located at equal distance from both lift points. In such a case, the potential increase of loading on one crane is directly related to the offset of the center of gravity.
See typical cases of unequal load distribution due to a non-symmetrical center of gravity.
This parameter should be determined during the planning and calculation of the lift. A non-symmetrical load will lead to unequal lifting forces. This may require different crane capacities.

2) Inclination of the load:

Load inclination can result from an uncoordinated movement of both cranes; this load inclination can occur during hoisting, lowering, luffing or even travelling (e.g. one crane is travelling on a ground surface not perfectly parallel to the ground surface of the second crane, listing of cranes on barges).
A load inclination often leads to a displacement of the center of gravity toward one crane or lift point. This results in an increase of the loading of that crane.
The effect also depends on the geometry and proportion of the load.

NOTE: Because it is impossible to ensure a perfect orientation of the load during the lift (inclination resulting from uncoordinated crane movements), it is advisable to <u>always</u> take into account a potential maximum inclination of the load as determined by the risk assessment (in following example, the engineer in charge of the lift calculation has determined that the maximum inclination of the load can reach 2,5°). The figure of 2,5° is an example only and does not mean that it corresponds to a value that can be used in any application. The inclination to be assumed corresponds to the unintended displacement (rotation), due to uncoordinated movements in a multiple lift until the effect is recognized and the movement is stopped or the displacement is corrected. As such the displacement depends on the accuracy of measurement and the reaction time.

The allowable inclination may also be expressed in allowable height difference between lifting points; this might be easier to monitor and understand in the field.

FEM provides a method and a simplified formula that covers both effects described above to determine the necessary de-rating of the cranes:

$$\%RC = \frac{100}{1 + \frac{h}{\min(a_1; a_2)} . \tan\alpha}$$

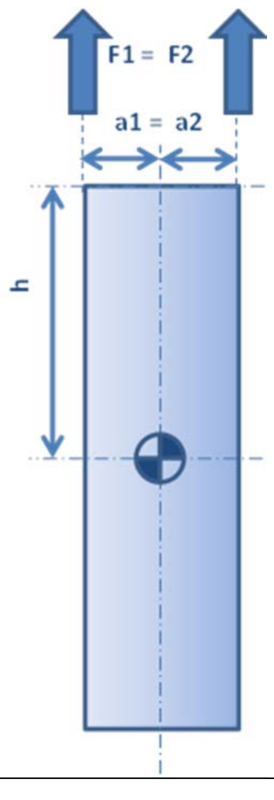
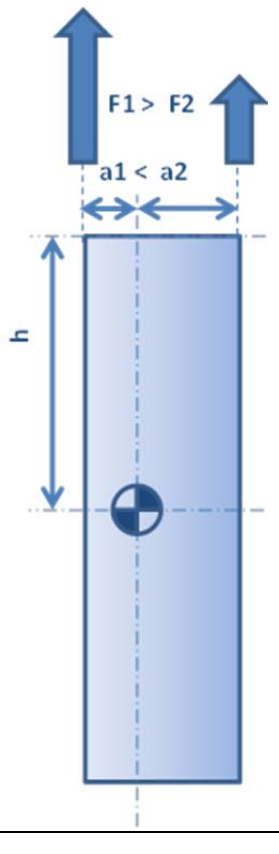
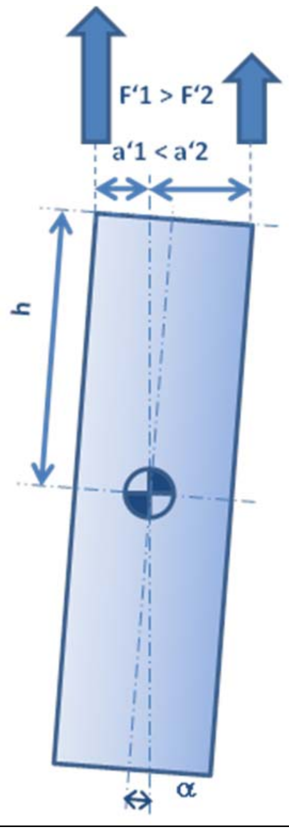
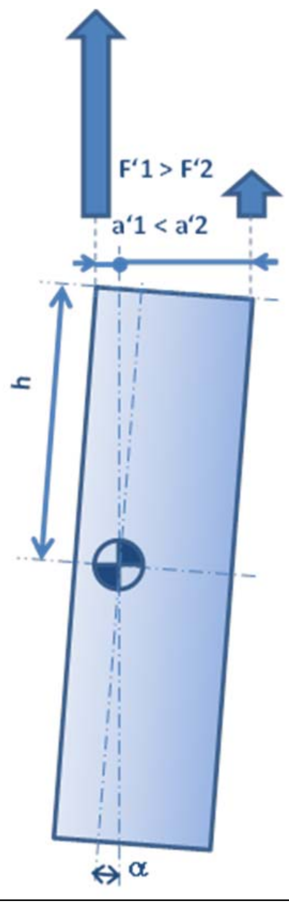
%RC: Percentage/Utilization of the crane’s capacity chart for each crane

h: distance between lift points and center of gravity measured parallel to the lifting direction. **NOTE: in these examples, the Center of Gravity is shown underneath the lifting points; if the Center of Gravity is higher than the lifting points, the load distribution between the cranes is inverted (refer also to Page 6).**

a_1, a_2: distance between lift points and center of gravity measured perpendicular to the lifting direction

α : Potential inclination of the load

Typical cases:

Case			
I	II	III	IV
Symmetrical	Non-symmetrical	Symmetrical	Non-symmetrical
α = 0 (vertical load)	α = 0 (vertical load)	α ≠ 0 (inclination from vertical)	α ≠ 0 (inclination from vertical)
			

The following examples show a method to determine the reduction of the cranes' capacity when lifting a load with 2 cranes depending on the position of the center of gravity of the load and the actual or potential inclination of the load.

Example for Case III

This example shows the potential load variation due to the inclination of the load, although the load is symmetrical (center of gravity is centric)

Load: **Symmetrical column**

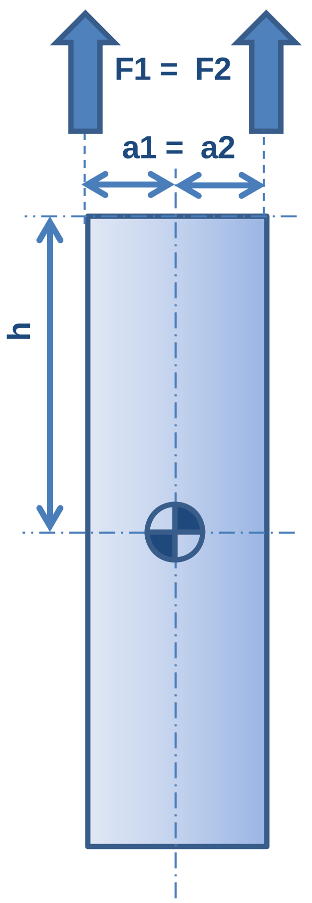
Dimensions: diameter 5 m
Height 40 m
Position Center of Gravity: 20m below upper attachment points

Lift with 2 cranes
Distance between attachment points 5 m

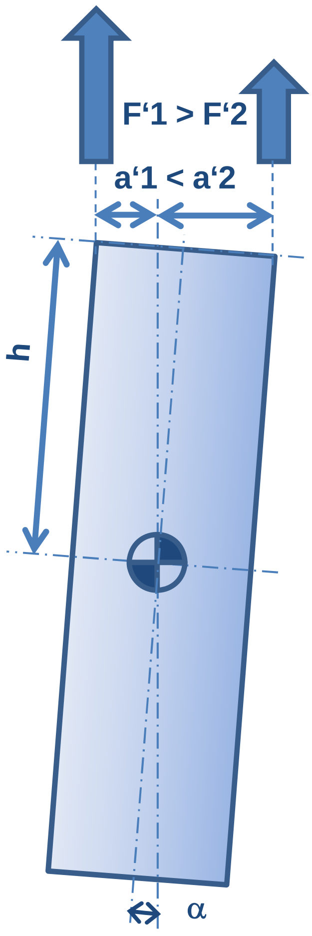
h = 20 m
a1 = a2 = 2,5 m (symmetrical load)
$h/a_{min} = 8$
α = 2,5° → this is the assumed maximum inclination that can be assured during the lift

NOTE: the inclination of 2,5° is not necessarily the actual inclination, but it corresponds to an assumed maximum inclination that can be ensured, based on the risk assessment and analysis made during the lift job preparation.

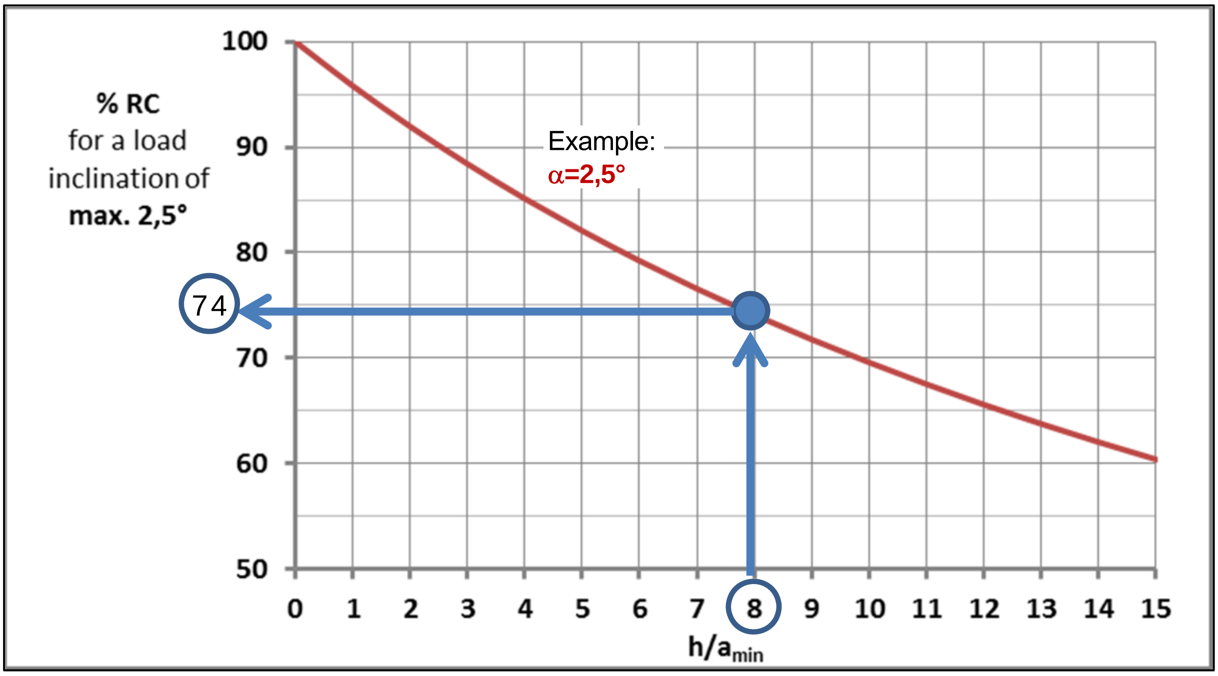
SITUATION 1: Load is perfectly vertical



SITUATION 2: Load is inclined by 2,5°



Therefore, in this example (based on an assumed max inclination of 2,5°), the lift should be planned with a maximum utilization of the cranes' rated capacity of 74% for each crane (see diagram)



Legend:

- %RC = Percentage/Utilization of the crane's capacity chart for each crane
- h/a_{min}= ratio between vertical and horizontal distance of the center of gravity of the load to the attachment points (see above sketch)
- a_{min}: Minimum of a1 and a2; in this case, $a_{min}=a_1=a_2=2{,}5m$

Example for Case IV

This example shows the potential load difference due to the center of gravity of the load not being centric.

Load: **Non-symmetrical load**

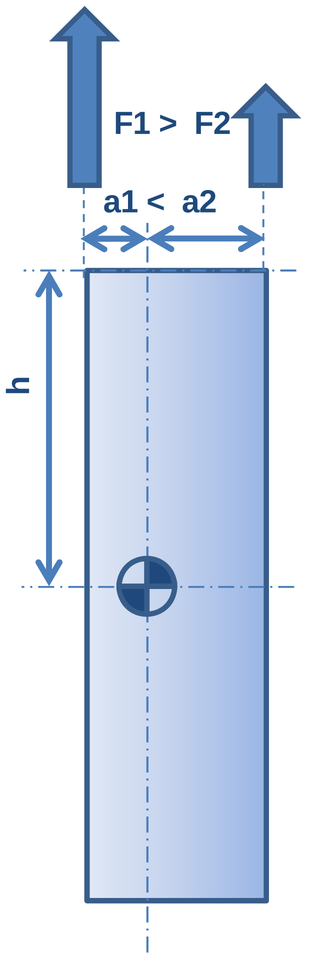
Dimensions: diameter 5 m
Height 40 m
Position Center of Gravity: 20m below upper attachment points

Lift with 2 cranes
Distance between attachment points 5 m

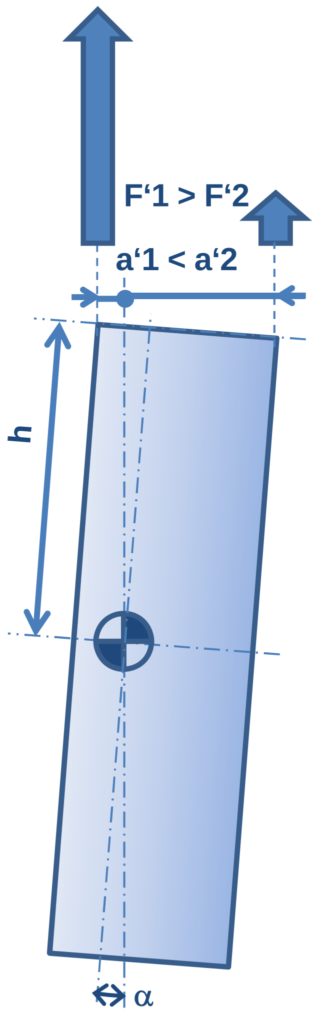
h = 20 m
a1 = 2m < a2 = 3 m (non-symmetrical load)
$h/a_{min} = 10$
$\alpha = 2{,}5°$ → this is the assumed maximum inclination that can be assured during the lift

NOTE: the inclination of 2,5° is not necessarily the actual inclination, but it corresponds to an assumed maximum inclination that can be ensured, based on the risk assessment and analysis made during the lift job preparation.

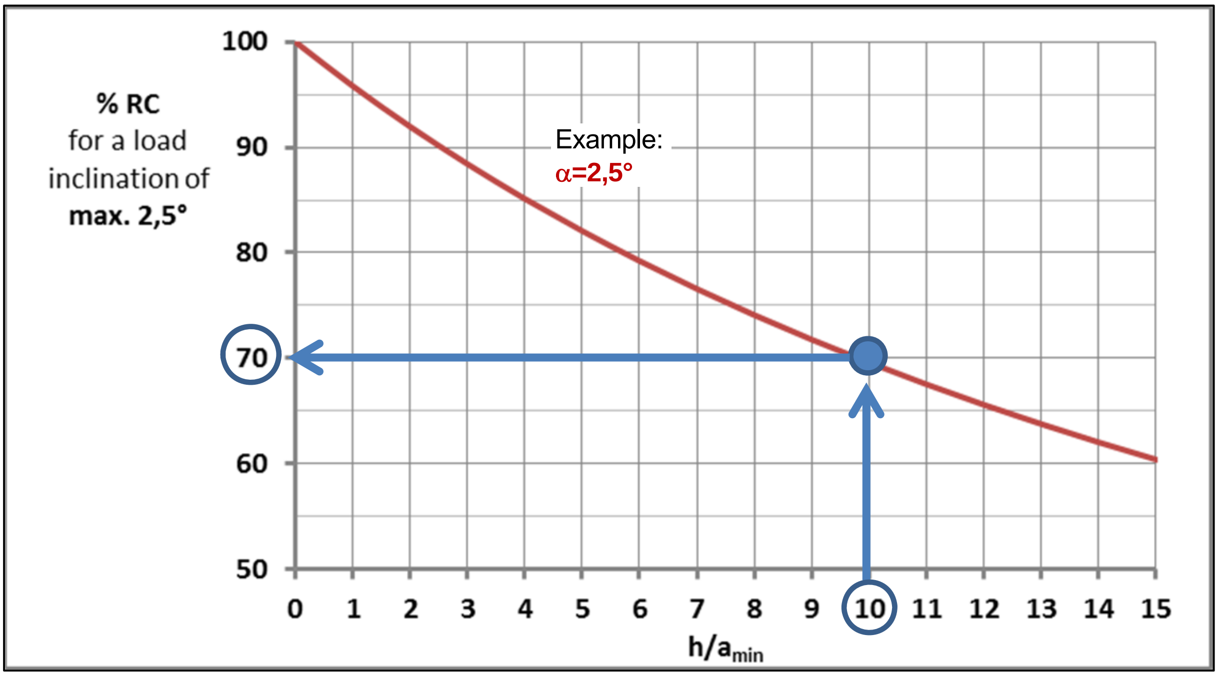
SITUATION 1: Load is perfectly vertical



SITUATION 2: Load is inclined by 2,5°



Therefore, in this example (based on an assumed max inclination of 2,5°), the lift should be planned with a maximum utilization of the cranes' rated capacity of 70% for each crane (see diagram)

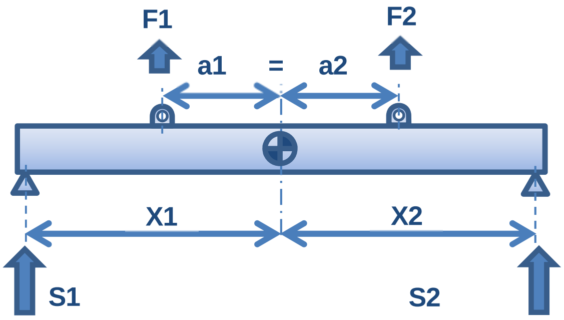


Legend:

- %RC = Percentage/Utilization of the crane's capacity chart for each crane
- h/a_{min}= ratio between vertical and horizontal distance of the center of gravity of the load to the attachment points (see above sketch)
- a_{min}: Minimum of a1 and a2; in this case, $a_{min}=a_1$= 2m

ANNEX 2 Influence of center of gravity and supporting points - Illustration

The illustration below shows a long beam resting on 2 support points.
Two cranes are used to lift the load.
In this example, both cranes are of equal capacity and the load, as well as the center of gravity, the lifting lugs and support points are symmetrical.

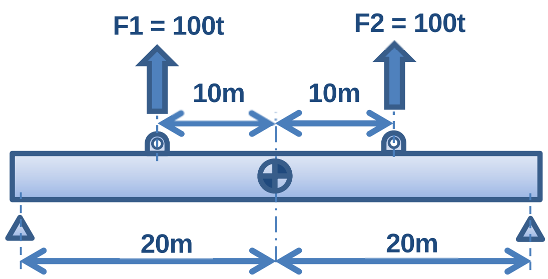


Legend and figures in this example:

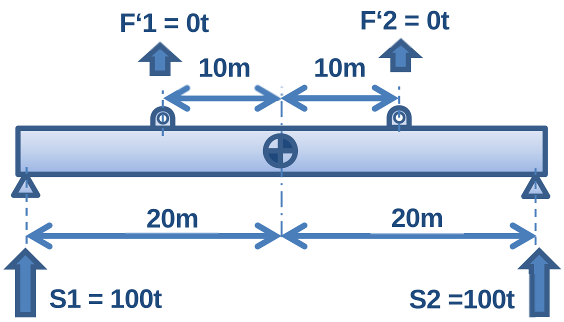
F1, F2:	Loads on Crane 1 and Cranes 2
S1, S2:	Reaction Force Support 1 and 2
a1 = a2 =	10m
X1 = X2 =	20m
Load weight =	200t

Case 1

Load suspended on both cranes
Before setting down on ground



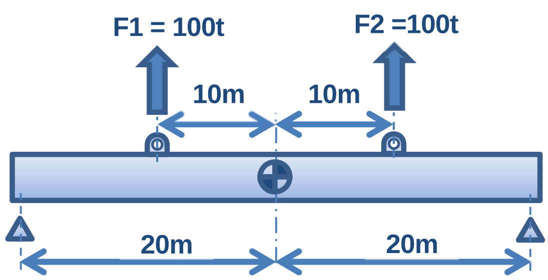
Load lowered by both cranes :
SIMULTANEOUSLY
touching both support points



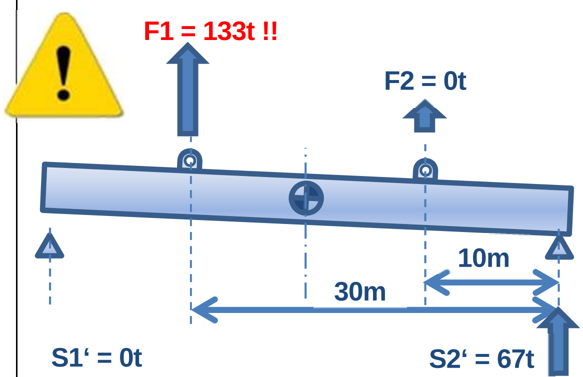
Both cranes release the load simultaneously from 100t to 0t

Case 2

Load suspended on both cranes
Before setting down on ground



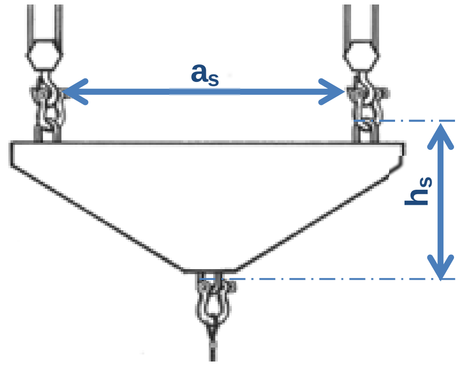
Load lowered by both cranes :
NOT SIMULTANEOUSLY
one side setting on support point FIRST



Crane 1 will suddenly get overloaded by 33% from 100t to 133t when right hand side will be set on the support point. This phenomenon depends among others on the elasticity of the load

ANNEX 3 Lift Rigging / Equalizer beams

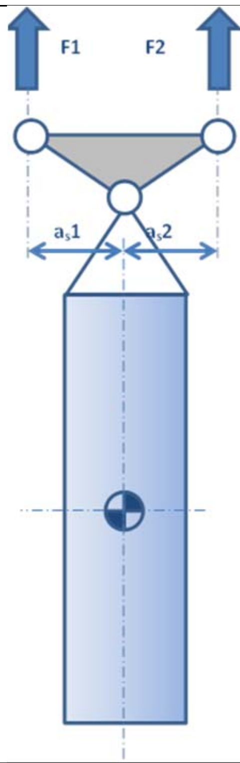
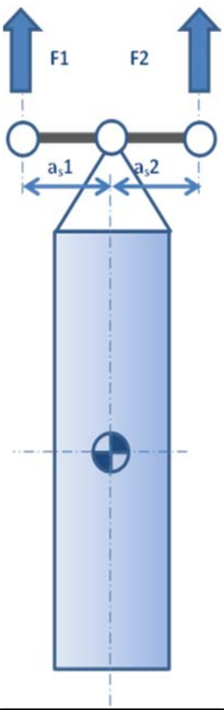
Equalizer beams are used to equalize the loads on several hoist lines when making multiple lifts. The picture corresponds to a spreader for a tandem lift, but similar frame-type devices exist for applications with more than 2 cranes.

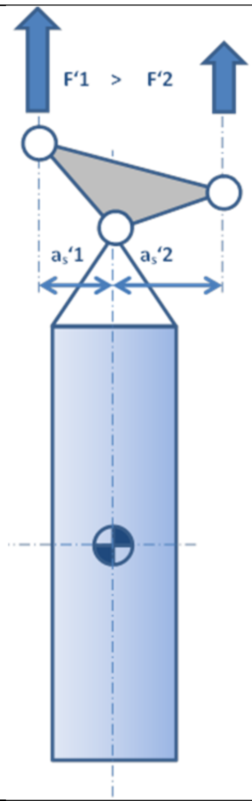
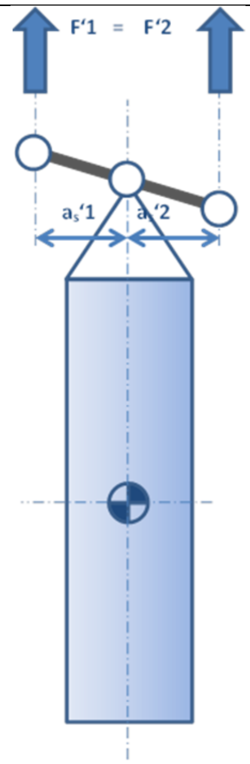


The selection of the spreader or equalizer beam has to be done carefully and along with the dimensioning of the beam (Safe Working Load), the geometry has to be taken into account. The effect described in Annex 1 can also happen when using equalizer beams.

The smaller the ratio h_s/a_s, the smaller the potential load difference; in other words, if the 3 points are on the same line (i.e. $h_s=0$), the lifting loads will remain equal regardless of the angle (inclination of the spreader).

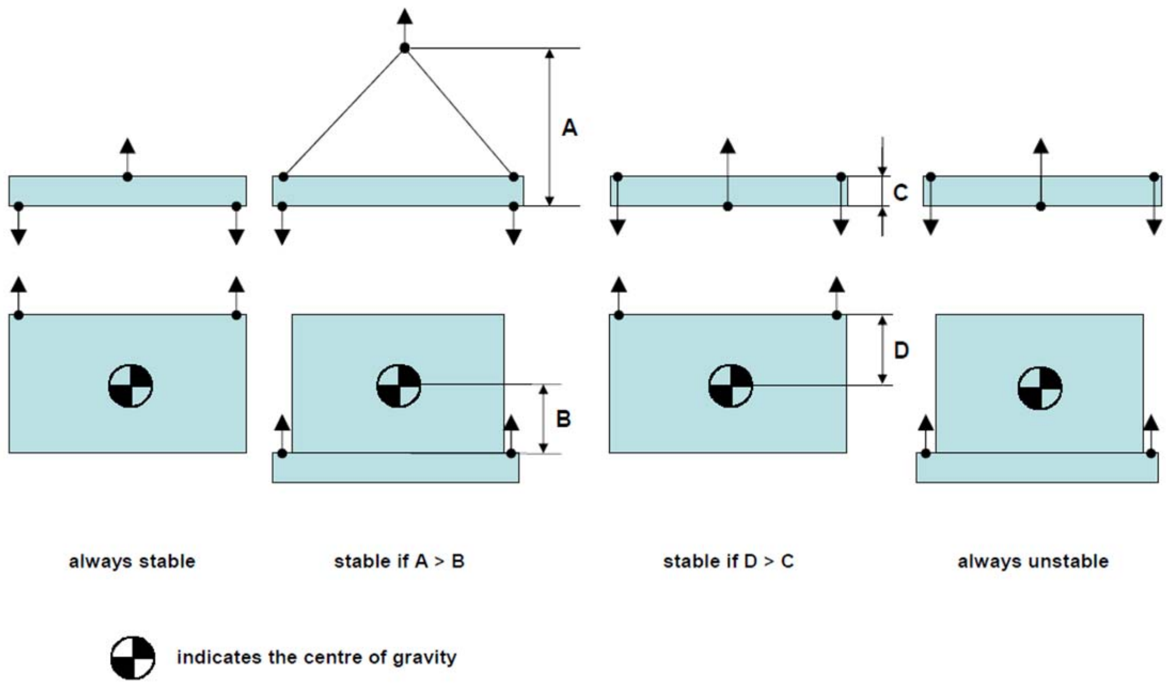
Illustration of the possible load shift in relation to the equalizer geometry, in case of uncoordinated crane movement:

Case			
I	II	III	IV
Non-inclined load	inclined Spreader	Non-inclined load	inclined Spreader
Spreader Height **h_s >0** **a_s'1 < a_s'2** **F'1 > F'2** **Crane loading will change if crane movements are not coordinated**		Spreader Height **h_s =0** **a_s'1 = a_s'2** **F'1 = F'2** **Crane loading will NOT change if crane movements are not coordinated**	
			

ANNEX 4 Positioning of Lifting Lugs

The figures below explain the effects of stable and unstable arrangements of lifting beams and support points (lifting points) on the load (compare EN13155 Chapter 7.1.2.5 Lifting beams). Forces which will try to topple the load will always be present (wind load, acceleration and deceleration of slewing, etc.).



5. REFERENCES

This document has been reviewed and jointly adopted by the following member associations ICSA:

- **Association of Equipment Manufacturers [AEM]**
- **The Crane Industry Council of Australia [CICA]**
- **The European Association of abnormal road transport and mobile cranes [ESTA]**
- **European Materials Handling Federation [FEM]**
- **Specialized Carriers & Rigging Association [SC&RA]**

This document is maintained by the Technical Committee of Product Group Cranes and Lifting of the European Materials Handling Federation [FEM].

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